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Interim Radon-Resistant Construction Guidelines for Use in Florida-1989

Florida Agricultural and Mechanical Univ., Tallahassee

Prepared for:

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16. ABSTRACT The report gives results of a project to investigate, analyze, and develop radon-resistant construction guidelines that are consistent with other building codes and that could be applied to Florida. A literature search resulted in information on radon remediation techniques, new construction methods, and existing radon-resistant building codes such as those in Sweden and Canada. The identified techniques were amended, modified, or supplemented for incorporation into draft model guidelines for new construction in format consistent with the Southern Building Code Congress International, Inc.'s Standard Building Code. A technical review advisory committee (including building contractors, architects, engineers, and representatives of federal, state, and local governments), formed during development of the guidelines, provided input and recommended changes to the draft guidelines. Although the project has resulted in guidelines for recommended construction practices, they should be coupled with a carefully planned and implemented program of experimentation. Eventually, this approach will lead to building code provisions that are scientifically defensible, cost effective, reliable, and easily incorporated into standard construction practice.

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INTERIM
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FOR USE IN FLORIDA - 1989

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ABSTRACT

This project was initiated with the objectives of investigating, analyzing and developing radon-resistant construction guidelines which are consistent with other building codes and which could be applied to Florida.

A literature search was conducted in which available information was obtained on radon remediation techniques, new construction methods and existing radon-resistant building codes such as those in Sweden and Canada. The Swedish codes had to be obtained and translated into English before they could be analyzed. The effectiveness of each technique was evaluated, and those techniques with specific application to southern construction were noted.

The techniques and procedures identified by the research were amended, modified or supplemented as needed for incorporation into draft model guidelines for new construction in a format consistent with the Standard Building Code promulgated by the Southern Building Code Congress International, Incorporated.

A technical review advisory committee which included building contractors, architects, engineers and representatives of federal, state and local government was formed during the development phase of the guidelines. The committee provided input and recommended changes to the draft guidelines, and as a consequence of these suggestions guidelines were finalized.

This report was submitted in fulfillment of Contract Number 7D4130NTGX under the sponsorship of the United States Environmental Protection Agency. This report covers a period from August 28, 1987 to June 27, 1988.

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INTRODUCTION

Over the past decade there has been a growing concern about the health effects associated with exposure to radon and its progeny. Florida is the first state in the nation to pass a rule establishing standards which set limits on radon progeny in buildings and there are numerous publications currently available addressing mitigation techniques. However, there are few studies documenting radon-resistant methods for new construction, and mitigation techniques may not be the most appropriate ones for new construction. In addition, there are many factors in the southeastern United States which make existing research conducted in the northeast difficult to apply here. These factors include geology, climate, common building practices and lifestyles.

While there may not yet be a consensus on the ideal radon-resistance features for buildings, the approach toward identifying such features should be two-fold. First, it is necessary to determine the likely entry routes for radon into the building. This research is rather complete, and although there is a better understanding of these processes being gained every day, it appears that future research in this area will provide refinement rather than revolution.

Second, those standard building practices and details that appear responsible for allowing radon into a structure should be examined in order to determine ways in which they could be modified to create a radon barrier. While it appears that much has been done in this area of research, it is still an area requiring much more investigation.

Most demonstration projects have incorporated several building modifications simultaneously. If reduction of the radon level one would expect from a standard home is the measure used, the results have been successful. However, because of the nature of the experiment each of these test homes represents, it is virtually impossible to correlate the observed results with the individual construction changes. In particular, the following basic questions remain unanswered:

- Which change from standard building practice is responsible for the observed effect?
- Are the changes introduced capable of standing alone, or is there an unrecognized synergistic relationship between them?
- Can the effects be replicated, and if so, with what reliability?
- What factor of safety, if any, is contained in the modification?
- To what extent is the observed effect a response to the higher quality control inevitable when an "experimental test house" is being constructed? Is such increased attention to quality a necessary part of the modification; would the feature be reliable if implemented broadly?
- Is there any degradation of the effect over time?
- Does the modification exceed provisions of an existing code or does it only mandate careful adherence to an existing standard?

Clearly this approach is impossible to implement without carefully executed, well planned and thorough research. Until such research is conducted, it is a real possibility that some building modifications might inadvertently cause more harm than good. This might take the form of unnecessary expense, lack of protection from radon gas concentrations within the home or large scale environmental harm caused by the wholesale implementation of an unresearched building technique.

For these reasons, this project has resulted in guidelines for recommended construction practices and should be coupled with a carefully planned and implemented program of experimentation. This approach will lead to building code provisions which are scientifically defensible, cost effective, reliable and easily incorporated into standard construction practice.

This study represents a critical evaluation of those building modifications which show promise of being reliable, reasonable and effective. From this evaluation, it should be possible to choose the method of radon reduction most applicable to a given situation. Included below is a brief description of the basic categories of radon reduction techniques with commentary on each.

The problem of elevated radon concentrations in homes can be approached from either of two directions: by filtering out or diluting the radon and its progeny once they are inside the dwelling, or by preventing the radon-carrying soil-gas from entering the home.

The first method has much to recommend it. It is generally accomplished without severe impact to the construction of the dwelling and can be added after completion with minimal additional expense. Hence, it has been used and tested in several homes, and under certain circumstances, it may be the technique of choice. Unlike other radon reduction strategies, this method will tend to address all indoor air pollutants. Thus, this method might solve indoor air quality problems not yet identified.

It has, however, several characteristics which make it a less than perfect solution:

- It has a rather high lifetime cost.
- As an active system (one with motor-driven components), it will require maintenance.
- It is susceptible to owner interference.
- It requires energy to operate.
- It has a negative impact on other energy conservation measures.

Although this may be an expensive choice for new construction, price alone is not a sufficient reason for it to be disallowed. Use of such a system would necessitate careful engineering in order to meet other code requirements regarding energy consumption, as well as to assure that the system is adequate for the source of radon involved.

The second method, preventing soil gas from entering a building, should be further subdivided into two classes: those which are totally passive and those solutions which require continuous energy inputs (active systems).

Of the truly passive systems, all consist of a mechanical barrier to the flow of soil gas. For concrete construction, the typical system includes the following essential components: a vapor barrier sealed at all penetrations and a concrete slab cast with special precautions to prevent cracking and cause a gas-tight seal to be formed at all penetrations. Although these systems are relatively easy to accommodate, they are not without problems. Many unresolved differences appear when the various systems are scrutinized:

- The thickness of the vapor barrier is not consistently specified.
- There appears to be no consensus on the question of sealing the vapor barrier to the foundation walls in conventional slab construction.
- There is no consensus on how to make joints in the vapor barrier, some literature recommending a 12" lap, others requiring a continuous seal with mastic.

- The relative effectiveness of the slab and vapor barrier are not proven separately. It is possible, therefore, that many test homes built with a 6 mil polyethylene vapor barrier "work" because of the integrity of the slab, and that the vapor barrier plays no role. In such cases, eliminating the sealing of the vapor barrier at penetrations, joints with foundation walls, and seams would have no negative impact on the effectiveness of the slab.
- Since the effectiveness of the slab independent of the vapor barrier is known in theory, the special plasticizers and the higher strength concrete, as well as the additional care required in finishing the concrete is specified with some confidence. It is possible, however, that the vapor barrier is capable of doing all the "work" and this additional expense is unwarranted.
- The limitations of slab dimensions recommended by some to prevent shrinkage cracking, run counter to the needs of the public and are not easily applicable to multi-family construction.
- Improved monolithic slab construction does not easily handle sloping ground. The wholesale leveling of land to create flat building sites would be an unfortunate by-product of over-application of this technique.

In general, however, it is clearly possible to construct slab-on-grade homes that are radon-resistant, and some combination of demonstrated techniques should be available which does this fairly economically.

Crawl space construction generally gets high marks from the literature, but this verdict is not unanimous. A serious concern is the interaction between adequate ventilation of the crawl space for radon resistance and minimized ventilation of it for energy conservation and comfort. Another serious concern is the lack of careful documentation within the literature of what exactly is meant by the term "crawl space."

The active systems are perhaps the most thoroughly tested and documented. This is due in part to the fact that it is relatively easy to add them to certain types of homes, and these housing types are heavily represented in the northeastern part of the United States. It is this area of the nation where much of the work on radon mitigation has taken place.

These active systems can be further divided into ones that draw soil gas from beneath the slab of a building and vent it to the outdoors where it is quickly diluted to safe concentrations, and those that attempt to reduce the emergence of soil gas by continually pumping a small volume of air beneath the slab.

Although either of these systems is believed to be less costly than the whole-house ventilation schemes described earlier, each has many of those same negative characteristics:

- As an active system (one with motor-driven components), it will require maintenance.
- Reports indicate a failure rate of close to 10 percent per year during the first few years of use for these systems. Fan failure or occupant tampering are often cited as problems.
- It is susceptible to owner interference.
- It requires energy to operate.

The first of these two active barrier systems, sub-slab depressurization, seems less sensitive to problems of imperfect sealing of the sub-slab from the house. In addition there is a relatively large body of experience to recommend the system for use in the areas where it has already been implemented.

However, the sub-slab depressurization systems have not been tested extensively in this region. While there appears to be no indication of trouble with these systems, serious side effects cannot be summarily dismissed as being impossible. Consider the following:

- There are currently about 200,000 housing starts per year in Florida. At an average of only 1400 square feet per slab, this method could potentially be employed on more than 10 square miles of soil per year.
- This system essentially "mines" radon, drawing it from the ground faster than it would normally escape. The long-term effect of this applied at large scale seems to deserve investigation.
- It can be assumed that the drawing off of soil gas will affect the soil moisture content beneath and for some small distance around each house where this method is employed. The long-term effect of this applied at large scale also seems to deserve investigation.
- In the climates where this method has been tested, slabs are usually at or slightly above soil temperatures. In Florida, the opposite would be true, especially in the summer.
- If soil gas were to condense on the underside of these slabs, which appears likely, could the chemical make-up and toxicity of the condensate be accurately predicted without experimentation?

Hence, it is probably too early in the process of discover to require widespread application of sub-slab depressurization systems, despite their being among the most frequently mentioned and best documented systems in northern climates. Until their safety and reliability in a southern climate is established, these systems should be installed on an experimental basis only.

The sub-slab pressurization systems are somewhat less common, but very similar in concept. They have the advantage of theoretically reducing the rate at which radon will escape from the sub-slab soil, due to the slightly elevated pressure. However, these systems appear to be more vulnerable to leakage of soil gas through the slab and into the living space for the same reason.

However, it is not clear why one would choose this system over sub-slab depressurization for new construction in Florida. The widespread use of this system is not recommended at this time.

A feature of all sub-slab systems is very important: it is possible to provide for them but not install the fan, and either block their air passages entirely or vent them through the roof like ordinary plumbing vents. Systems with unpowered vents through the roof have been noted as being ineffective in warm climates, but venting through the roof should do no harm, either.

This is not the most economical of solutions, and it serves no mitigation purpose until activated. However, it has the appeal of an insurance policy. It is a proven mitigation strategy that can be implemented if need be rather inexpensively. As such, it probably should be allowed. However, it is not yet apparent that passive venting or sub-slab rough-in should be required, since other passive radon barrier methods appear to be equally effective, potentially more reliable and less expensive.

SECTION 1 - GENERAL

PURPOSE AND LIMITS OF USE OF THESE INTERIM GUIDELINES

1.0.01 These Interim Guidelines are intended to provide assistance to residential designers and builders in the state of Florida who wish to incorporate current information on radon-resistant building practice into new residential construction.

1.0.02 These guidelines are intended to improve indoor air quality with respect to radon. Use of these guidelines is voluntary and does not guarantee radon will be limited to any specific concentration in a building. Although adherence to these interim guidelines does not guarantee that specific concentrations of radon will be achieved in the living space, the probability of reduced radon entry into the building is increased.

1.0.03 The radon-resistant building details suggested herein are generally based on assemblies or techniques which have been successfully incorporated into experimental houses and are reasonably well documented.

1.0.04 These guidelines are interim suggestions for radon-resistant building practice. In any jurisdiction where these guidelines appear to be in conflict with existing building codes, the local building official is urged to contact the Florida Department of Community Affairs, Division of Codes and Standards for clarification of the guidelines.

RADON IN HOMES

1.1.01 Radon is a radioactive gas which occurs naturally in many types of soil. It has been found in high concentrations in some areas of many states including Florida.

1.1.02 Radon rises from the ground and can accumulate in buildings. Radon and its radioactive by-products can cause lung cancer when breathed.

PRINCIPLES OF RADON RESISTANCE IN RESIDENTIAL CONSTRUCTION

1.2.01 This document addresses three generic approaches to limiting radon accumulation in buildings. They are:

A. Elimination:
Remove the radon from the soil before it reaches the points where it could enter the building.

B. Isolation:
Construct a radon barrier which either eliminates or so effectively reduces the passage of radon from the soil into the building that concentrations of radon in the building are acceptable.

C. Dilution:
Flush radon from within the building using ventilation air drawn in from outside.

1.2.02 Radon elimination systems, in general, mechanically or passively draw soil gas containing radon from beneath the building. When this technique is applied to slab-on-grade, slab-below-grade or basement construction, it is commonly called sub-slab depressurization, and is discussed in Section 7.

1.2.03 When the soil gas is removed from below a building with a crawl-space, it is most commonly accomplished with passive ventilation, which is discussed in Section 4.

1.2.04 Radon elimination systems are most effective when used in conjunction with the isolation techniques appropriate to the particular construction system used in the building.

1.2.05 Isolation systems attempt to create a mechanical barrier which will prevent the flow of radon. The details of each isolation system vary with the construction system being used. In order to provide the residential designer or builder maximum freedom to choose building systems, many different radon isolation system details are discussed in these guidelines. These systems are addressed in Sections 2,3,5,6 and 8.

1.2.06 It is important to note that many of the isolation systems discussed in these guidelines will not be applicable to certain construction systems. Residential designers and builders must exercise judgement in choosing those systems which are appropriate to their needs.

1.2.07 Isolation systems are highly recommended because they are passive, and frequently require only minor changes from standard building practice. However, it is exceedingly difficult to produce a true radon barrier, and the useful life of a new residence far exceeds the length of experience with these systems. Since sub-slab suction systems cannot be easily installed in existing buildings, it is highly recommended that they be roughed-in in accordance with the recommendations of Section 7.

USE OF THESE INTERIM GUIDELINES

1.3.01 Those construction details and practices which are most confidently recommended are marked with three asterisks (***). It is believed that these practices or details should be included in radon-resistant construction whenever applicable.

1.3.02 Those construction details and practices which are recommended, but with less confidence, are marked with two asterisks (**). It is believed that these practices or details will improve the radon-resistance of buildings and should be included in radon-resistant construction whenever applicable and economically feasible. Priority, however, should be given to those provisions with three asterisks when budget or other factors demand a choice be made between competing details or practices.

1.3.03 Those construction details and practices which are recommended, but with the least confidence, are marked with one asterisk (*). It is believed that under certain conditions, these practices or details may improve the radon-resistance of buildings. However, due to the complex relationship between these and other elements of the building, their effectiveness is uncertain. Priority should be given to those provisions with three, and then two asterisks when budget or other factors demand a choice be made between competing details or practices.

1.3.04 In some instances, lack of experience causes a detail or practice to be recommended with only one or two asterisks, but a more highly rated alternative detail or practice is not offered. In such instances, the recommended detail should be followed, but with the knowledge that its effectiveness is less fully proven.

SECTION 2 - ISOLATION MEMBRANES

USE OF A "VAPOR BARRIER" AS A SOIL-GAS RETARDER

*** **2.0.01** A soil-gas retarder should consist of at least one thickness of 6 mil or thicker polyethylene sheet, placed so as to provide a continuous barrier between the soil and the building floor.

*** **2.0.02** Soil-gas retarders should be installed so as to seal all of the floor area from the soil below. In order to achieve this seal, the soil-gas retarder should extend continuously from the top of the concrete footing or be sealed to the foundation wall, or extend to the outside edge of a monolithic slab or patio.

*** **2.0.03** Soil-gas retarders should be installed with great care and protected from puncture or other damage during the construction process.

*** **2.0.04** All penetrations of the soil-gas retarder, including accidental punctures or tears, should be repaired with the same material, lapped at least 12".

** **2.0.05** Soil-gas retarders should be installed with all seams lapped at least 12".

* **2.0.06** If a concrete slab is not placed over the soil-gas retarder, it should be inspected for proper installation and then protected from uplift and penetration with 2" minimum cover of clean masonry sand.

SECTION 3.0 - CONCRETE SLABS IN ISOLATION SYSTEMS

GENERAL

3.0.01 Concrete floor slabs can be an effective radon barrier provided the slab is free of cracks or other pathways for radon flow. The recommendations of this section seek to minimize cracking by improving common concrete placing and curing practices, and by using unrestrained slab edges which allow the slabs to shrink without cracking. In addition, the use of fiber-reinforcing and/or post-tensioning can reduce the tendency for cracking in slabs.

3.0.02 Other pathways for radon flow through concrete floor slabs are addressed as penetrations in Section 3.2.01.

3.0.03 Individual slabs should incorporate only those recommendations which are appropriate to their conditions.

SLAB-ON-GRADE CONSTRUCTION

*** **3.1.01** All concrete slabs used as floors for residences or attached patios, carports, garages, basements, storage rooms, or other spaces connected or adjacent to a residence, should be constructed in accordance with the provisions of this section.

*** **3.1.02** All concrete slabs should be placed and cured in accordance with the American Concrete Institute publication 302, Guide for Concrete Floor and Slab Construction. Specific recommendations of this publication include the following:

*** **(a)** Minimum 28 day compressive strength should be not less than 3000 pounds per square inch.

*** **(b)** If increased slump and workability of concrete is necessary, it should be achieved by the addition of a water reducing admixture (plasticizer) or high-range water-reducing admixture (superplasticizer) or by careful modification of mix design. Additional mixing water added on the job-site should be avoided.

*** **(c)** Slabs should be cured either with a membrane curing compound meeting the requirements of ASTM C 309 or kept continuously wet for 4 days after finishing to promote crack-free curing. This may be accomplished with a water spray, wetted burlap or any other method appropriate to ACI 302 recommendations. Curing should begin immediately following the final finishing operations.

*** **3.1.03** The inside corner created whenever a slab forms an "L" is especially vulnerable to shrinkage cracking. Two pieces of #4 or #5 reinforcing bar, three feet long and placed approximately 12" on center across areas where additional stress is anticipated, should reduce cracking and control crack width. Additional reinforcing steel should be placed across any point where one would expect a crack to occur.

*** **3.1.04** The use of fiber reinforced concrete floor slabs, mixed and placed in accordance with recommendations of the American Concrete Institute Committee 544 State-of-the-Art Report on Fiber Reinforced Concrete, should be carefully considered for limiting shrinkage cracking. With fiber reinforced concrete utilizing polypropylene or other flexible fibers, the vapor barrier may be less vulnerable to accidental puncture as well.

*** **3.1.05** The use of post-tensioned concrete floor slabs should be carefully considered for limiting shrinkage cracking.

VERTICAL PENETRATIONS AND JOINTS

*** **3.2.01** The penetration of a pipe or other object through the slab should be sealed by one of the following methods:

*** **(a)** Metallic pipe should be coated with asphalt or plastic roof cement over the entire area which will be in contact with the slab.

*** **(b)** A formed gap of at least 1/2" width should be created around the pipe to a depth of at least 1/2", and this gap should be fully filled with an approved caulk or sealant.

*** **(c)** Pipes of PVC or ABS material should fully contact the slab for the entire 3 1/2" depth of the slab. If the installation of a toilet flange or shower drain prevents 3 1/2" contact between a pipe and the slab, the pipe should be sealed in accordance with method (b) above.

*** **(d)** Where large work spaces are formed into a slab, such as beneath a bathtub drain, the exposed soil should be fully covered with a solvent based plastic roof cement or other suitable material to a minimum depth of 1".

*** **(e)** When stakes used to support plumbing, electrical conduits or other objects penetrate the slab, they should be sealed to the vapor barrier in accordance with Section 2.0.04, they should be sealed to the slab by either method (a) or (b) above, and they should be solid or have the open end sealed tightly. Such stakes should be of material resistant to decay, corrosion or rust.

*** **3.2.02** Vertical joints through the slab should be constructed in accordance with one of the following methods:

*** **(a)** The slab should be finished with a tooled edge of not less than 1/2" radius, and the depression caused by this tooling fully filled with an approved sealant or caulk.

*** **(b)** A recess of at least 1/2" width and at least 1/2" depth should be formed in the slab, and this recess should be fully filled with an approved sealant or caulk. Removable edge expansion joint material is acceptable for creating this recess.

*** **(c)** When neither of these methods is appropriate, and the joint is the boundary of a hole that is fully contained by the slab, the hole may be filled with shrinkage-compensating concrete in accordance with the manufacturer's instructions.

*** **(d)** Where patio, carport or other slabs described in Section 3.1.01 create a cold joint with the floor slab or foundation wall, this joint should be made in accordance with either (a) or (b) above.

3.2.03 Horizontal joints between the slab and masonry foundation walls should be constructed in accordance with one of the following methods:

** **(a)** The slab should extend across the entire top plane of the wall and bear on a smooth surface of solid concrete block, and be separated from the block with a continuous soil-gas retarder or other approved bond breaking material.

** **(b)** If the slab extends over only a portion of a masonry wall so as to create a vertical joint, as with "L" shaped slab edge blocks, the vertical joint should comply with Section 3.2.02 and the horizontal joint should comply with Section 3.2.03(a).

** (c) If the slab intersects the inside edge of the foundation wall, the slab edge should be treated in accordance with Section 3.2.02(a) or (b) and the top course of the foundation wall should be solid block or hollow block filled at least 4" deep with concrete.

SEALING CRACKS IN FLOOR SLABS

3.3.01 Cracks in concrete floor slabs that can create possible paths for radon to pass into the building should be sealed by one of the following methods prior to being covered by another material:

***(a) Cracks greater than 1/32" in width should be widened as necessary, thoroughly cleaned and filled with an approved sealant in accordance with the manufacturers recommendations.

*** (b) Cracks due to settlement or other structural movement should be sealed as in paragraph 3.2.02, but only after the cause of the cracking has been corrected.

SECTION 4.0 - CRAWL SPACE CONSTRUCTION

*** **4.0.01** Crawl space construction is defined for the purposes of these guidelines to include any building or portion of a building with floors that span over anything other than habitable space, regardless of the material used to construct the floor system.

CRAWL SPACE VENTILATION AS AN ELIMINATION SYSTEM

*** **4.1.01** Crawl spaces under buildings with perimeter foundation walls or another perimeter enclosure system should be equipped with screened vents on at least three sides of the foundation. Vents should be sufficient in size and number to provide at least 1 square foot of vent for each 150 square feet of crawl space, and should be located so as to provide good circulation of air across the crawl space. Vents should not have movable louvers or means for closure. Plumbing located in the crawl space should be adequately protected from freezing by insulation or means other than restriction of ventilation air.

SUBFLOOR JOINTS AND PENETRATIONS

*** **4.2.01** Subfloor construction should include an air infiltration barrier consistent with the Florida Energy Efficiency Code for Building Construction 903.2(f)2. Special attention should be given the following:

*** (a) Tongue and groove plywood floor decking should be applied with butt joints continuously glued to floor joists with a waterproof construction adhesive.

*** (b) All penetrations through the subfloor, including but not limited to plumbing pipes, wiring and ductwork, should be fully sealed with an approved caulk. Where large openings are created by plumbing, such as at bath tub drains, sheet metal or other rigid materials may be used in conjunction with sealants to fully close and seal the opening.

*** (c) Any vertical joint between the subfloor and foundation wall or the subfloor and any vertical plane of the building, which extends from crawl space to the top of the subfloor, should be fully sealed with an approved sealant or caulk.

CRAWLSPACE FOUNDATION WALLS

4.3.01 Masonry stem walls should be constructed so as not to create passageways from below finished grade to the crawl space.

* (a) All penetrations of utilities through the stem walls should be sealed with mortar or approved caulk or sealant.

* (b) The top course of masonry foundation walls should be solid masonry or filled with concrete.

SECTION 5.0 - SLAB BELOW GRADE AND BASEMENT CONSTRUCTION

5.0.01 Slab below grade construction is defined for the purposes of this guideline as any living space other than a basement with the finished floor below grade at any point along its perimeter.

5.0.02 A basement is a special case of slab-below-grade construction, defined for the purposes of this guideline as any living space with the finished floor an average of three feet or more below finished grade along one or more sides of the space.

*** **5.0.03** If a sump is necessary for water control or other purposes, it should have a gasketed and bolted lid with grommets and/or caulked seals around all pipe or wire penetrations.

FLOOR CONSTRUCTION

*** **5.1.01** Basement and slab-below-grade floor slabs should conform to the provisions of Section 2 and Section 3.

BELOW GRADE EXTERIOR WALL CONSTRUCTION

*** **5.2.01** Walls enclosing below grade living space should be constructed with a continuous waterproofing membrane applied to the outside surface from the top of the footing to finished grade. This membrane should be sealed to the top of the footing so as to completely seal the joint between the footing and the wall.

*** **5.2.02** The top course of any masonry wall enclosing below grade living space should be a solid masonry material or should be filled with concrete.

SECTION 6.0 - COMBINED CONSTRUCTION TYPES

6.0.01 Where slab-on-grade, slab-below-grade, basement, or crawl space construction are combined in one structure, the provisions for each construction type should be met in the appropriate area.

*** **6.0.02** A wall located between a crawl space and the living space should be constructed to protect against radon flow from the crawl space into the living space. Special care should be taken to minimize the penetrations and openings in these walls, and to seal all potential paths of radon entry.

** **6.0.03** Walls separating crawl space from living space should comply with the infiltration reduction provisions of Section 10 and/or the provisions of this section.

** **6.0.04** When a door must be located in a wall between a crawl space and the living space, it should be fully weatherstripped or gasketed.

** **6.0.05** Any openings which connect a crawl space and the space between ceiling joists or wall studs of an adjoining living space should be fully blocked and sealed.

** **6.0.06** Openings for electrical or plumbing connections in a wall between a crawl space and the living space should be sealed with an approved caulk and/or gasket.

SECTION 7 - SOIL-GAS VENTILATION SYSTEMS

** **7.0.01** Concrete floor slabs should be equipped with the components of an approved soil-gas removal system that cannot be added after completion of the structure, other than by excavation or removal of elements of the completed building.

** **7.0.02** Soil-gas removal systems should be roughed-in only below slabs fully surrounded by footings and stem walls or monolithic foundation slabs.

*** **7.0.03** Soil-gas removal systems should conform to the current recommendations of the United States Environmental Protection Agency and the Florida Radon Mitigation Study - Phases 1 and 2.

SECTION 8 - OTHER ENTRY PATHS FOR RADON

8.0.01 It is the intent of this section that no opening should be knowingly created or allowed to exist in a building if that opening can serve as a path for soil gas to enter the living space or the crawl space of a residence.

PRESSURE DRIVEN FLOW OF RADON INTO A BUILDING

** **8.1.01** The flow of radon into a building is affected by small pressure differences between the inside and outside air. In order to minimize the flow of radon into the home, the following precautions are recommended for all construction types:

(a) All openings in top and bottom plates of frame construction, including interior partitions, should be closed with an approved caulk or sealant in accordance with Section 8.2.

(b) Any fuel burning fireplace, wood stove or furnace should be provided with combustion air from outside the living space in accordance with Section 9.1.

(c) Air handling ducts should be carefully sealed in accordance with Section 9.2.

FRAME WALL CONSTRUCTION

8.2.01 In order to minimize the pressure driven flow of radon within walls, all walls should conform to the provisions of this section.

*** **(a)** All penetrations through the sole plates of walls on raised wood floors should be sealed.

** **(b)** Attic access openings should be located outside the living space whenever possible. When located within the living space, they should be weatherstripped to minimize exfiltration of air from the living space.

** **(c)** Ceiling lights should be fitted with infiltration gaskets or sealed.

* **(d)** All penetrations in interior and exterior surfaces of walls, including plumbing and utility entrances, electrical outlets and switches should be sealed with an approved gasket or caulk.

* **(e)** All joints and cracks in interior and exterior surfaces of walls, including but not limited to window and door frames should be caulked.

* **(f)** Penetrations through the top plates of all walls should be sealed.

VENEERS AND WALLS WITH VERTICAL AIR SPACES

* **8.3.01** The exterior wall sheathing of any building that creates a vertical air space in the wall between the sheathing and the exterior veneer should include an air infiltration barrier conforming to Florida Energy Efficiency Code for Building Construction, 1986, 903.2(g). Such barrier may include:

* (a) Plastic film (perm > 0.5) attached to the outside of the framing and sealed continuously to the top and sole plates and around openings and at seams with adhesive.

** (b) Sheathing board set vertically so joints split a stud and sealed at all joints between boards and at top and sole plates.

** (c) Closed cell foam insulation board set as in Section 8.3.01(b) or set horizontally if edges are fitted tongue and groove joints.

* **8.3.02** Buildings described in Section 8.3.01 should be constructed so that the air space between the sheathing and the veneer does not extend below the finished grade.

* **8.3.03** The opening through veneers for crawl space ventilation should be constructed so as not to allow soil gas from the crawl space to enter the cavity between the veneer and the wall sheathing.

HOLLOW CONCRETE BLOCK OR MASONRY WALLS

* **8.4.01** All openings for electrical boxes or plumbing or other wall penetrations in hollow masonry walls should be fully sealed.

SECTION 9 - SPACE CONDITIONING SYSTEMS

9.0.01 Depressurization of buildings can result from cracks and openings in the building envelope, air duct system leakage or the location of air-handling equipment. This can increase the entry rate of radon into a building. Care should be taken to minimize the depressurization of houses.

HEATING AND AIR-CONDITIONING EQUIPMENT

** **9.1.01** Combustion heating systems should be provided with outside combustion air and dilution air from outside the living space in accordance with the Standard Gas and Mechanical Code.

** **9.1.02** Mechanical equipment rooms or closets adjacent to the living space containing combustion heating equipment should be completely sealed from the living space by caulking cracks and penetrations and weatherstripping doors. Combustion air MUST be provided in accordance with 9.1.01 above if the mechanical room is sealed as described in this paragraph.

** **9.1.03** Air-handling equipment should be located in crawl spaces bounded by stem walls only if fully enclosed in accordance with Sections 8.2 - 8.4.

*** **9.1.04** Condensate drains should connect to air outside the perimeter of the building envelope. Condensate drains that connect to dry wells or other soil may become direct conduits for soil gas, and can be a major entry point for radon.

DUCT SYSTEMS

** **9.2.01** All duct systems should be designed to operate at not more than 2.0" w.g. unless the system is entirely located such that all air leakage from the system will be into conditioned space.

** **9.2.02** Any metal duct located outside the conditioned space should have all joints sealed in accordance with the provisions of its listing.

** **9.2.03** Fibrous glass ducts and duct systems should be constructed in accordance with manufacturer's specifications, and all joints should be sealed in accordance with the provisions of the listing.

** **9.2.04** Flexible duct systems should have all joints sealed in accordance with the provisions of its listing.

*** **9.2.05** Return air ducts should not be located in a crawl space or beneath a slab.

*** **9.2.06** Supply ducts should not be located below concrete slab-on-grade or slab-below-grade floors.

*** **9.2.07** Special care should be given to sealing any supply ductwork located in a crawl space.

SECTION 10 - APPROVED MATERIALS, CAULKS AND SEALANTS

*** **10.0.01** No generally recognized standards for radon transmissivity of materials currently exist. The builder should rely upon the experience of those conducting radon related research projects for guidance in selection of specific building products for radon resistance. Published information from the United States Environmental Protection Agency and the National Association of Homebuilders National Research Center should be consulted for information regarding any product to be used for radon resistance. All materials should be applied in accordance with manufacturer's recommendations.

*** **10.0.02** Caulks and sealants generally shown most effective and durable in radon mitigation studies are those with single-part urethane bases or polysulfide bases. Silicone based caulks are acceptable. Water soluble caulks are not considered adequate.

*** **10.0.03** Solvent based asphalt products which readily flow at 70^{O}F are considered acceptable as coatings or soil-gas retarder adhesives, provided they are applied to dry surfaces in sufficient thickness to provide a continuous coating of the surfaces.

** **10.0.04** Asphalt based products wnich do not readily flow at 70^{O}F should be used only where coatings described in Section 10.0.03 will flow off the surfaces being treated. These products should be carefully applied to dry surfaces to insure no air bubbles are formed, and to provide a continuous coating of the surfaces.

* **10.0.05** Closed cell foams are acceptable as sealants in wood only, and should be continuously protected from sunlight.

SECTION 11 - ILLUSTRATED DETAILS

11.0.01 The following details show a variety of ways in which the recommendations of these guidelines can be met in residential slab and foundation construction. As with all other portions of these guidelines, the illustrations are intended to provide options to the residential designer or builder. Other details which are not illustrated, but which are in keeping with the recommendations of the guidelines are encouraged.

Figures 1 - 3 illustrate slab edges as outlined in Section 3.2.02(b), a common concrete block foundation wall in compliance with Section 3.2.03(c), and various vapor barrier / foundation wall details in conformance with Section 2.

Figure 4 illustrates a monolithic slab conforming to Section 3.1, and the vapor barrier detail for a monolithic slab edge as described in Section 2.

Figures 5 - 7 illustrate various slab edge details using solid "L" blocks in conformance with Section 3.2.03(b).

Figure 8 illustrates a slab edge conforming to Section 3.2.03(a)

Figures 9 - 11 illustrate slab edges conforming to Section 3.2.02(a), a common concrete block foundation wall in compliance with Section 3.2.03(c), and various vapor barrier / foundation wall details in conformance with Section 2.

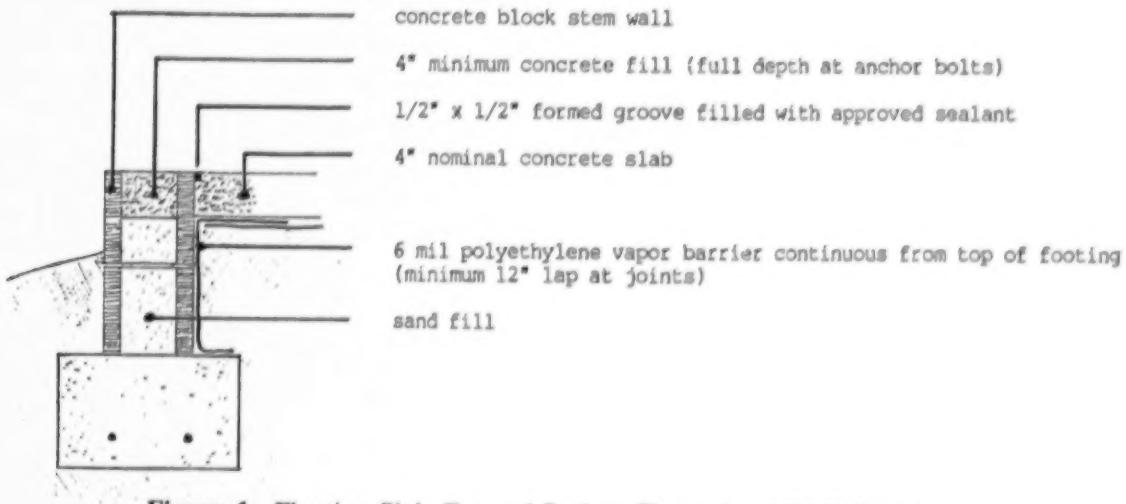
concrete block stem wall
4" minimum concrete fill (full depth at anchor bolts)
1/2" x 1/2" formed groove filled with approved sealant
4" nominal concrete slab
6 mil polyethylene vapor barrier continuous from top of footing (minimum 12" lap at joints)
sand fill

Figure 1: Floating Slab, Formed Sealant Channel and Wall Curtain

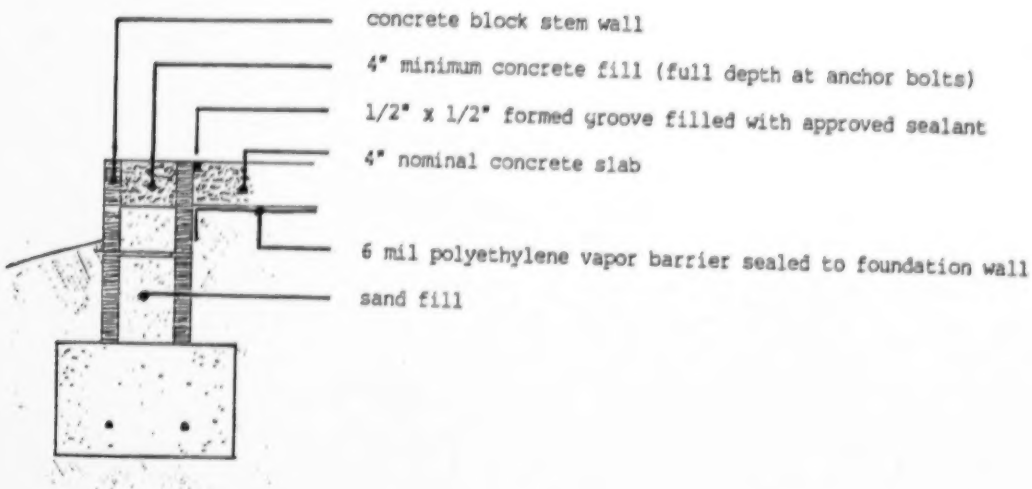
concrete block stem wall
4" minimum concrete fill (full depth at anchor bolts)
1/2" x 1/2" formed groove filled with approved sealant
4" nominal concrete slab
6 mil polyethylene vapor barrier sealed to foundation wall
sand fill

Figure 2: Floating Slab, Formed Sealant Channel and Vapor Barrier Sealed Down Wall

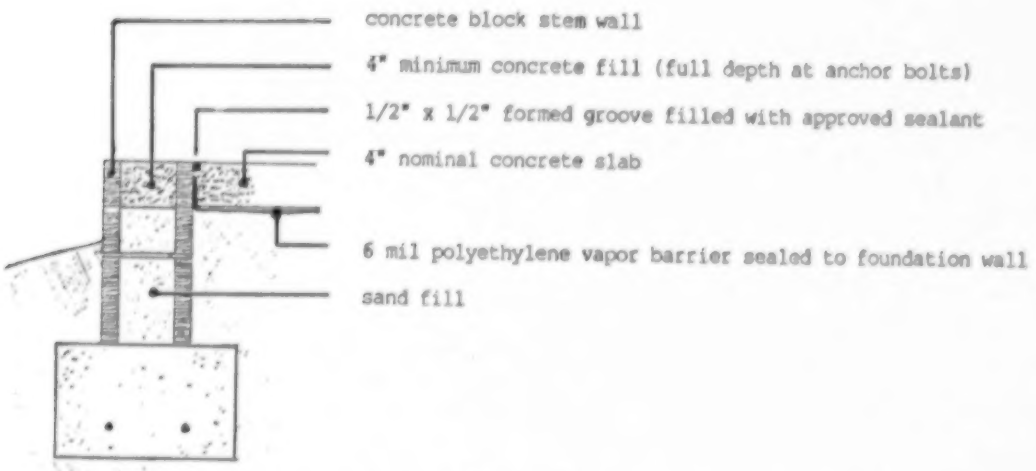
concrete block stem wall
4" minimum concrete fill (full depth at anchor bolts)
1/2" x 1/2" formed groove filled with approved sealant
4" nominal concrete slab
6 mil polyethylene vapor barrier sealed to foundation wall
sand fill

Figure 3: Floating Slab, Formed Sealant Channel and Vapor Barrier Sealed Up Wall

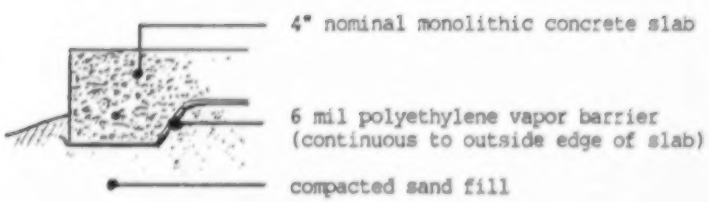
4" nominal monolithic concrete slab
6 mil polyethylene vapor barrier
(continuous to outside edge of slab)
compacted sand fill

Figure 4: Monolithic Slab Edge

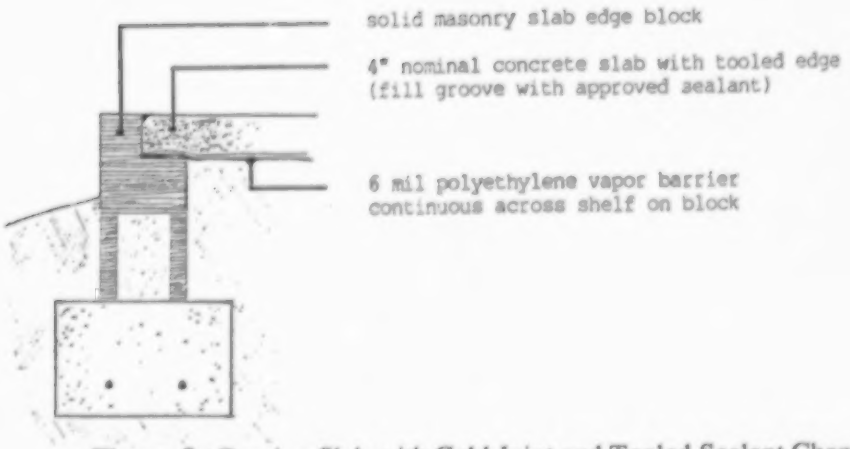
solid masonry slab edge block
4" nominal concrete slab with tooled edge
(fill groove with approved sealant)
6 mil polyethylene vapor barrier
continuous across shelf on block

Figure 5: Bearing Slab with Cold Joint and Tooled Sealant Channel

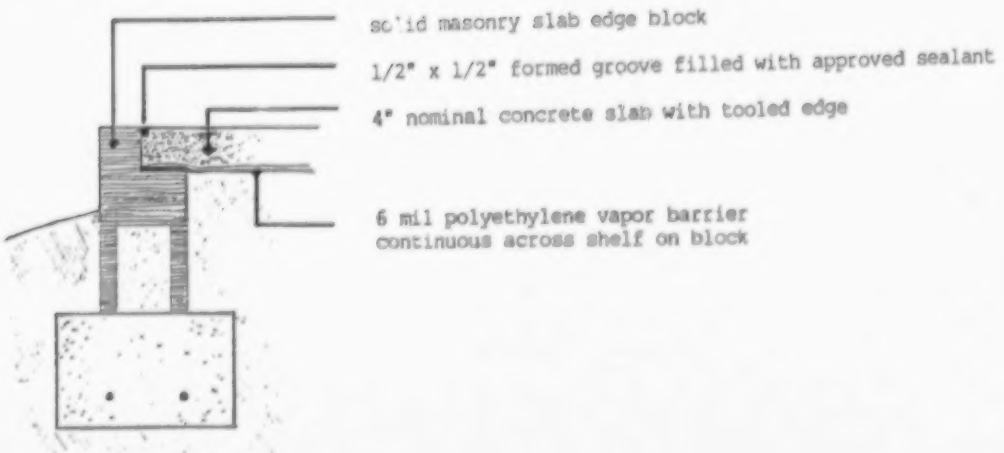
solid masonry slab edge block
1/2" x 1/2" formed groove filled with approved sealant
4" nominal concrete slab with tooled edge
6 mil polyethylene vapor barrier
continuous across shelf on block

Figure 6: Bearing Slab with Cold Joint and Formed Sealant Channel

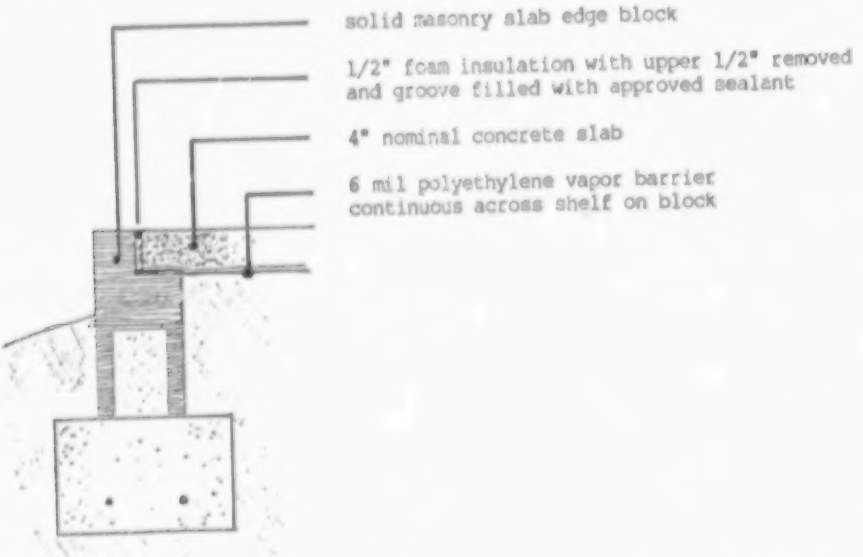
solid masonry slab edge block
1/2" foam insulation with upper 1/2" removed and groove filled with approved sealant
4" nominal concrete slab
6 mil polyethylene vapor barrier continuous across shelf on block

Figure 7: Bearing Slab with Expansion Joint and Formed Sealant Channel

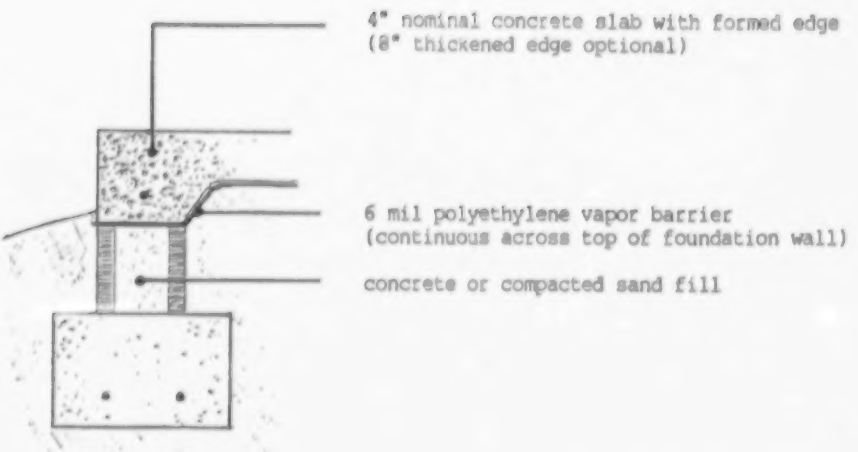
4" nominal concrete slab with formed edge (8" thickened edge optional)
6 mil polyethylene vapor barrier (continuous across top of foundation wall)
concrete or compacted sand fill

Figure 8: Modified Monolithic Slab Edge

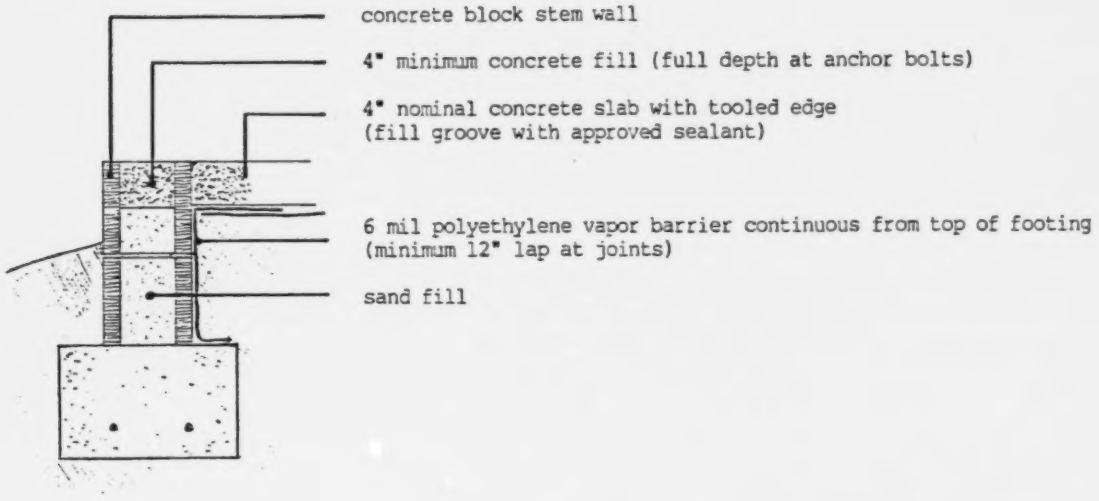
concrete block stem wall
4" minimum concrete fill (full depth at anchor bolts)
4" nominal concrete slab with tooled edge
(fill groove with approved sealant)
6 mil polyethylene vapor barrier continuous from top of footing
(minimum 12" lap at joints)
sand fill

Figure 9: Floating Slab, Tooled Sealant Channel and Wall Curtain-A

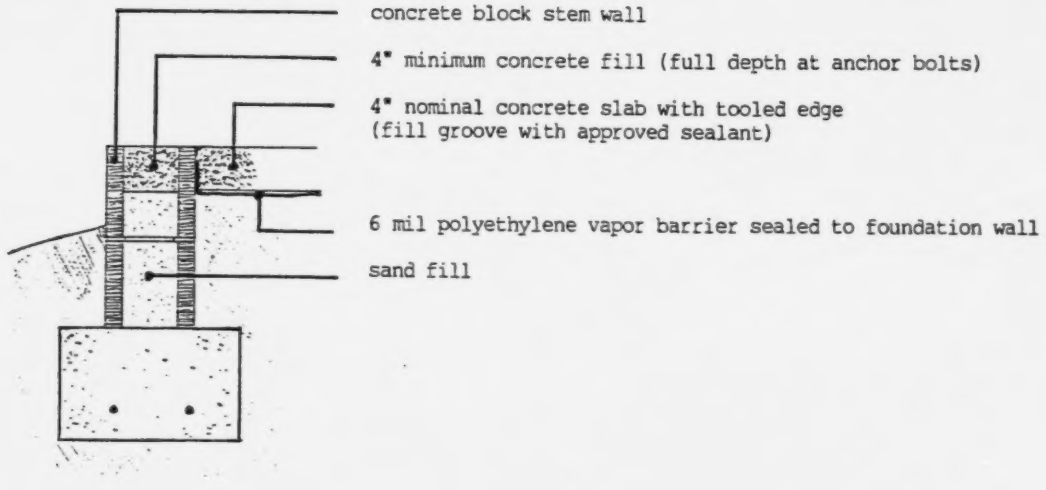
concrete block stem wall
4" minimum concrete fill (full depth at anchor bolts)
4" nominal concrete slab with tooled edge
(fill groove with approved sealant)
6 mil polyethylene vapor barrier sealed to foundation wall
sand fill

Figure 10: Floating Slab, Tooled Sealant Channel and Wall Curtain-B

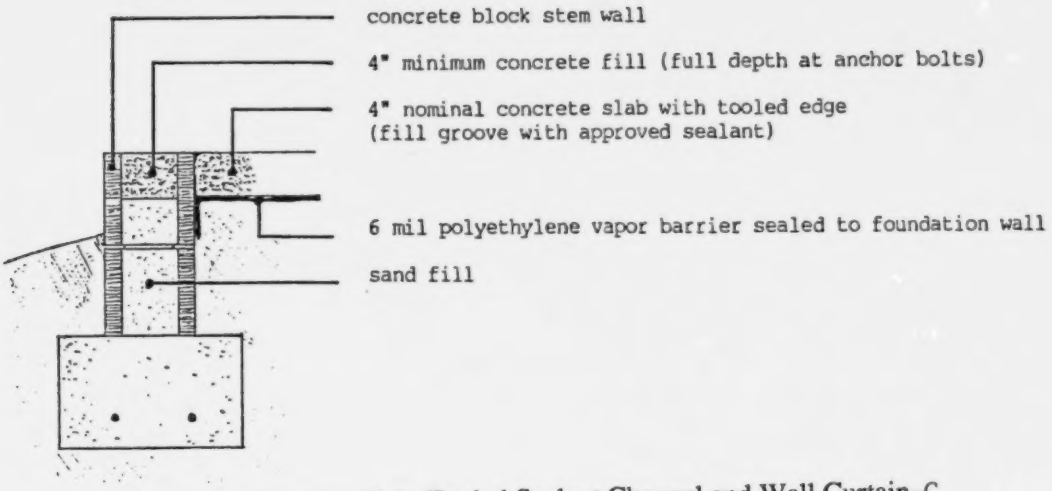
concrete block stem wall
4" minimum concrete fill (full depth at anchor bolts)
4" nominal concrete slab with tooled edge
(fill groove with approved sealant)
6 mil polyethylene vapor barrier sealed to foundation wall
sand fill

Figure 11: Floating Slab, Tooled Sealant Channel and Wall Curtain-C

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Box 19150
Redford Station
Detroit, MI 48219

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2740 Centerview Drive
Tallahassee, FL 32399-2100

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Florida Department of Health and Rehabilitative Services
Office of Radiation Control
1317 Winewood Boulevard
Tallahassee, FL 32399-0700

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900 Montclair Road
Birmingham, AL 35213-1206

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